METHOD AND APPARATUS FOR CONTROLLING A POWER LEVEL OF A SUBSCRIBER UNIT OF A WIRELESS COMMUNICATION SYSTEM

Patent Number:	WO9418756
Publication date:	1994-08-18
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Requested Patent:	☐ WO9418756
Application Number:	WO1994US00835 19940124
Priority Number(s):	US19930016446 19930211
IPC Classification:	H04B1/00
EC Classification:	H03G3/20D2, H04B7/005B1K
Equivalents:	MX9401116
Cited Documents:	US4777653; US4580262; US4228538; US5239667; US5245629

Abstract

After setting a subscriber unit to a transmit power level (12) which provides a signal at a base site having a target quality level, a fading characteristic of a communication channel between the subscriber unit and a base site is measured (13). The fading characteristic is then compared with threshold values (14). The measuring (13) and comparing (14) are repeated until the fading characteristic crosses a threshold (15, 60, 62). Once the fading characteristic crosses the threshold, the target quality level is set to a new target level (16, 61, 63). A subscriber unit (70) designed to accomplish this method comprises a receiver (72) which receives an RF signal. The received signal is averaged in an averaging device (73) and compared with the original signal in a differential amplifier (74). The output of the comparison is used by a controller (75) to determine power control adjustments to a transmitter (76).

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : H04B 1/00	A1	(11) International Publication Number: WO 94/18756 (43) International Publication Date: 18 August 1994 (18.08.94)

(21) International Application Number: PCT/US94/00835

(22) International Filing Date: 24 January 1994 (24.01.94)

(30) Priority Data:
08/016,446 11 February 1993 (11.02.93) US

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(81) Designated States: CA, JP, KR, SE.

Published
With international search report.

(54) Title: METHOD AND APPARATUS FOR CONTROLLING A POWER LEVEL OF A SUBSCRIBER UNIT OF A WIRELESS COMMUNICATION SYSTEM

(57) Abstract

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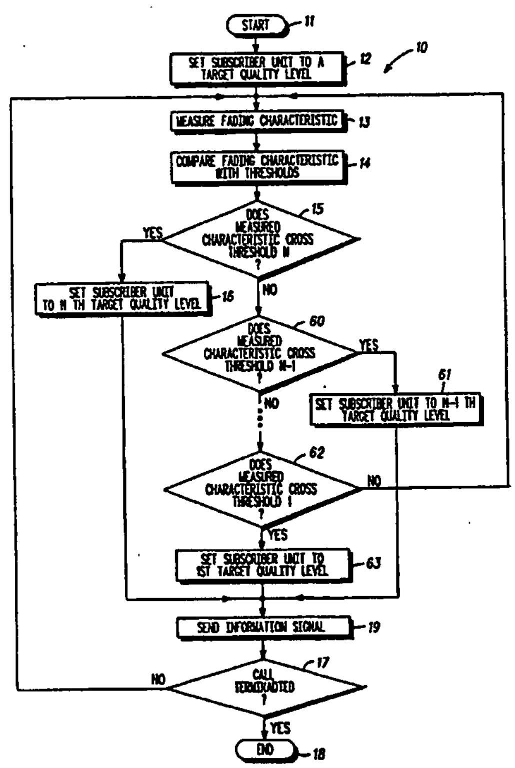

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METHOD AND APPARATUS FOR CONTROLLING A POWER LEVEL OF A SUBSCRIBER UNIT OF A WIRELESS COMMUNICATION SYSTEM

Related Inventions

The present invention is related to the following inventions, all assigned to the assignee of the present invention:

A Method for Compensating for Capacity Overload in a Spread Spectrum Communication System, having Serial No. 783,751, and filed on October 28, 1991; and

A Method for Controlling Transmission Power in a Communication System, having Serial No. 268,822, and filed on November 7, 1987.

Field of the Invention

The present invention relates, in general, to wireless communication systems and, more particularly, to a method and apparatus for controlling a power level of a subscriber, or remote, unit of a wireless communication system.

Background of the Invention

In Code Division Multiple Access (CDMA) environments, it is desirable to maintain the energy used per bit as compared to the noise in a given bandwidth (E_b/N_o) at a level where the signal is received sufficiently well (e.g. has sufficient quality) from the subscriber unit. However, while raising the E_b/N_o level would provide a high quality call (e.g. by causing the subscriber to increase its transmit power), it would also reduce the system capacity since the signal (E_b) of one call within the bandwidth is

interference (N_o) to other calls. Therefore, it is also desirable to keep the E_b/N_o level as low as possible while still providing a suitable quality signal. For a more detailed description of the power level/capacity trade-off, reference is made to co-pending U.S. patent application having Serial No. 783,751, identified above.

In order to accomplish this objective, present proposals use a power control loop to set the E_b/N_o to a desired level based on the Word Error Rate (WER). When the mobile is stopped, or moving at low speeds - e.g. rates less than 10 Kilometers Per Hour (KPH) - the E_b/N_o is gradually reduced to a level that is lower by a decibel (dB) or two than when the vehicle is moving faster. A higher E_b/N_o is necessary in a faster moving vehicle to maintain the WER in a propagation environment which is more hostile. The WER is measured to determine power adjustments to be transmitted to the subscriber unit. These adjustments serve to maintain a nominal E_b/N_o level. In practice, the mobile transmit power is gradually reduced which results in a reduced E_b/N_o and increased WER. Once the WER exceeds a certain limit, the mobile transmit power is raised to a level where the WER at the base site is acceptable. The process then repeats. This process is referred to as a power control loop.

However, as the mobile unit begins moving in excess of the "low speed" the WER will increase at a rate beyond which the low level E_b/N_o can be maintained. Once the WER increases past a preset point (threshold), or accelerates at a given rate, the system will gradually increase the E_b/N_o level (i.e. by increasing the subscriber transmit power) to a higher level required at higher speeds.

However, a problem with the present system is the delay in shifting from one E_b/N_o level to another. This

type of delay can result in one of two related and undesirable events which occur when the subscriber changes speed or stops. A change in speed results in a change in the required E_b/N_o; causing a degradation in the quality of the channel due to the delays in the power control loop. The first event is that, from a signal perspective, the E_b/N_o is now less than what is considered good for the system. This causes a poorer acceptable signal quality in the channel. The other event is that, from a system perspective, the E_b/N_o is now greater than what is required causing increased noise in the bandwidth for other subscribers.

Therefore, it would be desirable to reduce the transition time from one E_b/N_o level to another to as short a time period as possible to avoid degrading the overall bandwidth quality and/or capacity.

Summary of the Invention

A method of controlling a power level of a subscriber unit of a wireless communication system having a target quality level is provided. The method comprises, after first setting a target quality level for said subscriber unit to a first target quality level, adjusting the power level of the subscriber unit to generate a signal providing the first target quality level when received at a base site. A fading characteristic of the communication channel between the subscriber unit and the base site is then measured and compared with a threshold value. The measuring and comparing are repeated until the fading characteristic crosses the threshold. Once the fading characteristic crosses the threshold, the subscriber unit is set to a second target quality level.

An apparatus to accomplish the above method is provided by a subscriber unit having a receiver to receive an RF signal. The received signal is averaged in an averaging device and the average is compared with the original RF signal in a comparing device. The output data of the comparison is provided to a first control unit which uses the comparison information to provide target quality level information.

Brief Description of the Drawings

FIG. 1 is a block diagram of a flow chart illustrating a process embodying the present invention;

FIG. 2 is a power control graph illustrating one embodiment of the present invention;

FIG. 3 is a power control graph illustrating the operation of a prior art method;

FIG. 4 is another power control graph providing a comparison of the present invention with the prior art;

FIG. 5 is a prior art graph representing a multipath fading characteristic and variation by speeds;

FIG. 6 is a prior art graph representing fading characteristic probabilities as a function of speed;

FIG. 7 is a prior art graph showing normalized level crossing rates;

FIG. 8 is a block diagram of a power control portion of a subscriber unit designed to operate with the method of FIG. 1; and

FIG. 9 is a block diagram of a power control portion of a base site designed to operate with the method of FIG. 3.

Detailed Description of the Drawings

Referring initially to FIG. 1, a block diagram of a flow chart illustrating a process, generally designated 10, embodying the present invention is shown. Process 10 starts at block 11 when a call is established. Once established, depending on the speed of the subscriber, a first target E_b/N_o level (or first target quality level) will be selected. This will result in the subscriber unit being directed to a transmit power level which will provide that first target E_b/N_o level at the base site. As shown in FIG. 2, there are several different target E_b/N_o levels illustrated by lines 21-24. Ideally, the target E_b/N_o level of line 21 would be utilized at high speeds (e.g. above 45 KPH) and the target E_b/N_o level of line 24 would be utilized at lower speeds (e.g. 15 KPH or less). It should be noted that any number of target E_b/N_o levels can be defined in a system.

In FIG. 3, a prior art graph, generally designated 100, is depicted representing actual E_b/N_o levels over time. As a vehicle's speed changes, the WER rate improves permitting the transmit power to be reduced, resulting in a lower E_b/N_o. The E_b/N_o level is gradually reduced (using a power control loop), line 98, over potentially several seconds until an unacceptable threshold word error rate (WER) is exceeded. The mobile is then given a command to raise its power level. The remote units reaction is represented by line 99. These steps are repeated continuously as shown.

In FIG. 4, a composite graph, generally designated 110, is illustrated showing E_b/N_o adjustments using the prior art and the present invention. When the speed of the remote unit, represented by line 111, changes, the prior art method results in the changes to E_b/N_o represented by line 112. Here, the prior art would

reach a nominal level (WER threshold) at point 200. The results from the present invention are illustrated by line 113. As shown, the present invention reacts faster and reaches the nominal E_b/N_o level sooner than line 112.

Additional improvement can be found by combining the two techniques. Once the target E_b/N_o level is set and the mobile's transmit power is adjusted accordingly, the power control loop will be used to reach the nominal E_b/N_o level. This is illustrated by line 111. With the addition of the present invention, the same nominal E_b/N_o level is reached at point 201. Much sooner than the prior art.

As an example, a subscriber unit starting at around 40 KPH will be used. Therefore, the first target E_b/N_o level will be target E_b/N_o level 3, represented by line 22, FIG. 2. Once process 10 has been set to the target level, the fading characteristic of the signal is measured, step 13, FIG. 1. The fading characteristic may be a multipath fading characteristic, a Rayleigh fading characteristic, a Doppler shift measurement, or some other indicator of nulls and their frequency and may be measured at the subscriber or base site.

A multipath fading characteristic is illustrated in FIG. 5, a prior art graph, generally designated 30. Solid line 31 represents a stationary subscriber unit. As shown, even while stationary, the fading characteristics would seem to indicate movement. From a practical implementation, a stationary subscriber can encounter nulls at a rate indicating movement on the order of 10 KPH. This results from the movement of other things such as vehicles, other subscribers, etc., about the present subscriber.

When the subscriber increases speed, the nulls will appear more frequently, as represented by dashed line

32, FIG. 5. Therefore, the number of fades in a given period is generally representative of the speed of the subscriber.

Returning now to FIG. 1, once the fading characteristic is measured, it is compared to a threshold value. This is illustrated in the prior art graph of FIG. 6, generally designated 40, which shows a graph of the frequency (N_R) of fades as a function of velocity (V). The fades are measured in the number of level crossings per second (Hertz or Hz) and the velocity in KPH. The graph of FIG. 6 is derived using equation (1):

$$N_R = (f_m)(x) \tag{1}$$

where:

f_m is the Doppler shift in Hz; and

x is a constant which can be obtained from the graph of FIG. 7.

The graph of FIG. 7 is a prior art graph representing normalized level crossing rates. This graph is described in detail in Jakes, "Microwave Mobile Communications", pg 35 (1974). If it is assumed that, for p=1, any fade which crosses the average value will be counted as a fade then, using the graph of FIG. 7, the value of N_R/f_m is 0.915. In order to determine N_R, f_m must first be determined using equation (2):

$$f_m = (1.5)(V)(.62)(F) \tag{2}$$

where:

V is the velocity in KPH;

F is the frequency in GigaHertz (GHz);

the constant .62 is used to convert velocity (V) in equation (2) from MPH to KPH; and

the constant 1.5 represents several combined constants and scale factors.

Using equation (2), the Doppler shift at 10 KPH for a 1 GHz signal is 9.3 Hz. Substituting this into equation (1) provides a crossing rate, N_R, of 8.5 level crossings per second. As discussed above, a null crossing rate equal to 10 KPH is considered the maximum a stationary subscriber may encounter from the environment. At 15 KPH, one of the E_b/N_o transition levels (FIG. 2), the crossing rate is 12.8. At 30 KPH, where the E_b/N_o drops to level 2, the crossing rate is 25.6. These crossing rates (12.8 and 25.6) are two of the preset frequencies that act as threshold values used for comparison in step 14, FIG. 1.

If the fading characteristic crosses threshold level N (decision step 15) then the target quality level for the signal received from the subscriber unit is set to the N^{th} target quality level, step 16. If this measurement is made by the subscriber, then fading data is sent to the base site, step 19. Process 10 proceeds to determine if the call has been terminated, decision step 17. If the call has been terminated, process 10 ends, step 18. If the call is not terminated, then process 10 loops back to step 13.

If the fading characteristic does not cross threshold level N, then process 10 determines, decision step 60, if the fading characteristic crosses threshold level N-1. If level N-1 is crossed, then the target quality level for the signal received from the subscriber unit is set to the $N\text{-}1^{th}$ target quality level, step 61. Process 10 then proceeds to transmit step 19 and decision step 17.

This process of checking each of the threshold levels continues until decision step 62 is reached where process 10 determines if the measured characteristic

crosses threshold level 1. If level 1 is crossed, then the target quality level for the signal received from the subscriber unit is set to the 1^{st} target quality level, step 63. Process 10 then continues with transmit step 19 and decision step 17. If level 1 is not crossed, process 10 loops back from decision step 62 to step 13.

In the prior art, the system would have continued to measure the WER while the subscriber slowly decreased its transmit power. The E_b/N_o of the subscriber unit, as measured at the base site, would be allowed to continue to decrease until a poor WER was detected. The power of the subscriber unit is then increased until an acceptable WER was reached. During the delay between when the power of the subscriber could have been reduced and when the power was actually reduced, as shown in FIG. 4, the subscriber was using spectrum in excess of that needed. This ultimately detracts from the overall spectrum available for that bandwidth. Therefore, it is desirable to cause the transition between the target E_b/N_o levels to occur with as little delay as possible.

In the present invention, once the transition has occurred, the resulting WER is again measured and the power control loop is used to adjust the transmit power of the subscriber unit to fine tune the quality.

A block diagram of one embodiment of a power control portion of a subscriber unit, generally designated 70, is provided in FIG. 8. In FIG. 8, a signal is received from a base site 79 by antenna 71 and carried to receiver 72. Receiver 72 processes the signal and forwards the result to a circuit 78 to detect the threshold crossings of the received signal.

Circuit 78 is comprised of a filter 73 for averaging the signal from receiver 72; and a differential amplifier 74 to compare the averaged signal

with the original signal. The differential output data from circuit 78 is provided to a controller 75. The fading information is compared in controller 75 with a plurality of threshold levels. When a threshold is crossed, controller 75 signals the base site by transmitter 75 through antenna 77. Alternatively, this fading information could be forwarded to the base site continuously as a part of the standard overhead message. The decision on whether a threshold has been exceeded could then be made the base site; or at the subscriber unit as before. It should be noted here that antenna 71 and 77 may be the same antenna if a duplexer is used in subscriber unit 70.

While the design of circuit 78 and the method of FIG. 2 provide an advantage over the prior art. Further improvement, as shown by line 111 of FIG. 4, can be obtained from using circuit 90 illustrated in FIG. 9. Circuit 90 shows a block diagram of a base site embodying a combination of the prior art with the present invention. The output of the target power controller 93 is output to a summer (or combiner) 92. The output of controller 93 is based upon the fading data received from the subscriber unit. Also input to summer 92 is the output of a nominal power controller 91. Controller 91 operates at the direction of the power control loop. The sum of these controllers is then used to create an adjustment command to be transmitted to said subscriber unit by transmitter 94 through antenna 95. This results in the signal illustrated by line 111 of FIG. 4.

As an alternative to having the remote unit taking all of the measurements and making the various decisions, it should be understood that some of the measurements (e.g. Rayleigh fading) could be made at the base station. The base station would then direct

adjustments to the subscriber unit. Conversely, actions currently performed by the subscriber unit could be made at the base site.

Thus, it will be apparent to one skilled in the art that there has been provided in accordance with the invention, a method and apparatus for controlling a power level of a wireless communication system that fully satisfies the objects, aims, and advantages set forth above.

While the invention has been described in conjunction with specific embodiments thereof, it is evident that many alterations, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alterations, modifications, and variations in the appended claims.

Claims

1. A method of controlling a power level of a subscriber unit of a wireless communication system, said wireless communication system having a target quality level for a signal received at a base site from said subscriber unit, said method comprising the steps of:

(a) setting said target quality level to a first target quality level;

(b) adjusting said power level of said subscriber unit to generate said signal providing said first target quality level when received at said base site;

(c) measuring a fading characteristic of a communication channel between said subscriber unit and said base site;

(d) comparing said fading characteristic with a threshold value; and

(e) setting said target quality level to a second target quality level if said fading characteristic crosses said threshold value.

2. The method of claim 1 further comprising the step of repeating said steps (b) through (d) until said fading characteristic crosses said threshold.

3. The method of claim 1 further comprising the step of reducing said power level of said subscriber unit if a word error rate (WER) does not exceed a threshold WER.

4. The method of claim 1 wherein said wireless communication system is a Code Division Multiple Access (CDMA) system.

5. The method of claim 1 wherein said fading characteristic is measured by said subscriber unit.

6. An apparatus for controlling a power level of a subscriber unit of a wireless communication system, said apparatus comprising:

receiving means for receiving a first radio frequency (RF) signal;

averaging means for averaging said first RF signal, said averaging means providing an averaged RF signal;

comparing means for comparing said averaged RF signal with said RF signal, said comparing means providing a differential signal;

first control means, coupled to receive said differential signal, for generating a data representing a change in said target quality level; and

transmitter means, having an input coupled to said first control means, for transmitting said data.

7. The apparatus of claim 6 further comprising:

first control means, at said base site, for providing a first power adjustment indicator based upon a change in said target quality level;

second control means, at said base site, for providing a second power adjustment indicator if a word error rate (WER) does not exceed a threshold WER; and

combining means, at said base site, for combining an output from each of said first and second control means and providing a combined power adjustment indicator.

8. A method of controlling a power level of a subscriber unit of a wireless communication system, said wireless communication system having a target quality

level for a signal received at a base site from said subscriber unit, said method comprising the steps of:

(a) setting a target quality level to a first target quality level;

(b) measuring a frequency at which a signal strength of a radio frequency (RF) signal received by said subscriber unit crosses an average of said signal strength of said RF signal;

(c) comparing said frequency with a plurality of preset frequencies corresponding to a plurality of desired target quality levels; and

(d) setting said target quality level for said signal from said subscriber unit to one of said plurality of desired quality levels if said frequency crosses one of said plurality of preset frequencies.

9. A method of controlling a power level of a subscriber unit of a wireless communication system, said wireless communication system having a target quality level for a signal received at a base site from said subscriber unit, said method comprising the steps of:

(a) setting a transmit power level of said subscriber unit to provide said signal at said base site a first target quality level;

(b) reducing said transmit power level of said subscriber unit if a word error rate (WER) does not exceed a threshold WER;

(c) measuring a fading characteristic of a communication channel between said subscriber unit and said base site;

(d) comparing said fading characteristic with a threshold value;

(e) setting said transmit power level at said subscriber unit to provide said signal at said base site

having a second target quality level if said fading characteristic crosses said threshold; and

(f) repeating said steps (b) through (e).

10. A method of controlling a power level of a subscriber unit of a wireless communication system, said wireless communication system having a target quality level for a signal received at a base site from said subscriber unit, said method comprising the steps of:

(a) setting said target quality level for a signal received from said subscriber unit to a first target quality level;

(b) measuring a frequency at which a signal strength of a radio frequency (RF) signal received by said subscriber unit crosses an average of said signal strength of said RF signal;

(c) comparing said frequency with a preset frequency representing a threshold level;

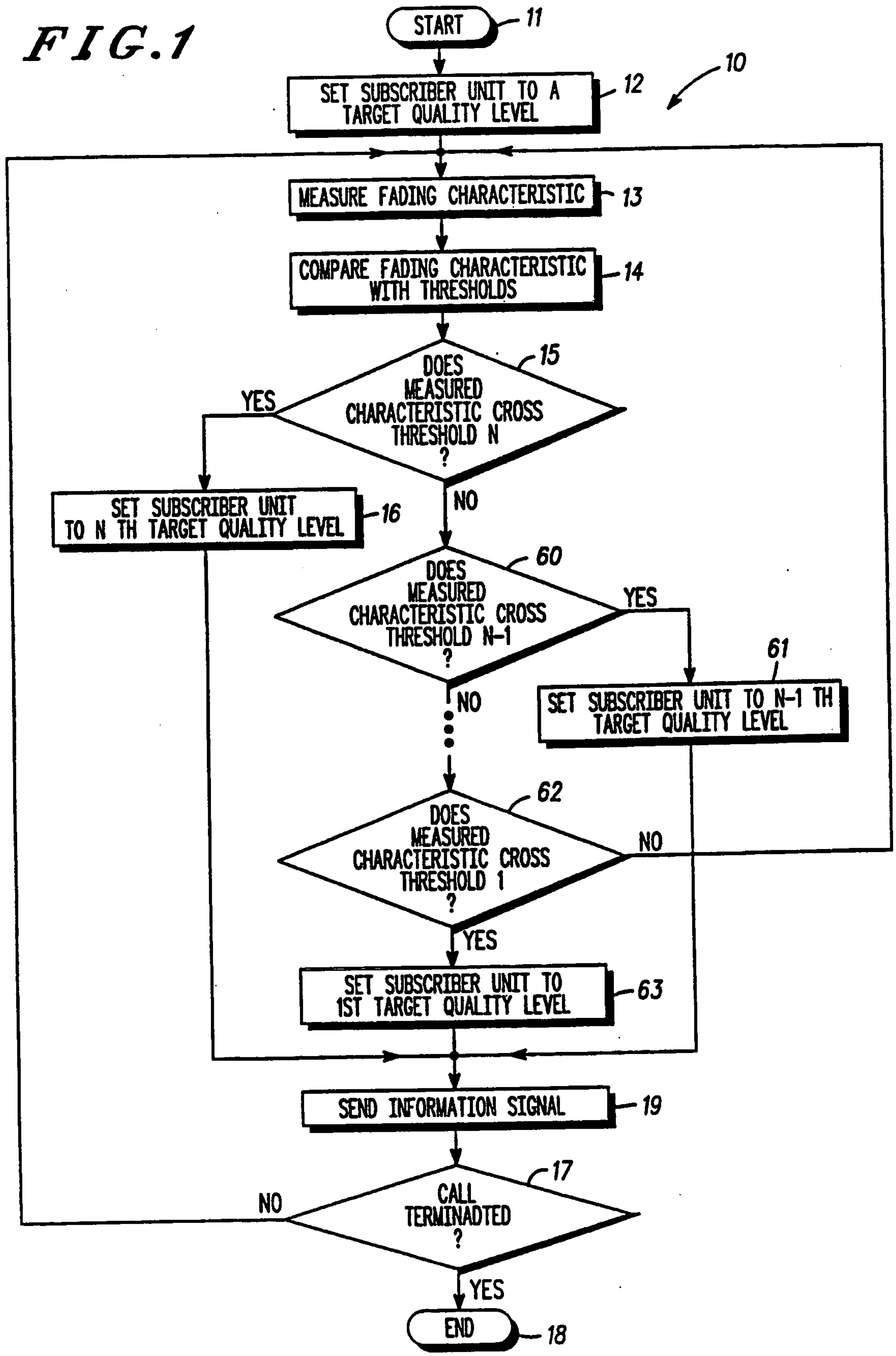
(d) setting said target quality level of said signal received from said subscriber unit to a second target quality level, less than said first target quality level, if said frequency is less than said preset frequency representing said threshold level;

(e) sending a command to said subscriber unit to reduce said transmit power level if a word error rate (WER) does not cross a threshold value;

(f) sending a command to said subscriber unit to increase said transmit power level if said WER does cross said threshold value; and

(g) repeating said steps (b) through (f) if said target quality level of said subscriber unit is not set to said second target quality level.

FIG.1


START
11
10
SET SUBSCRIBER UNIT TO A TARGET QUALITY LEVEL
12
MEASURE FADING CHARACTERISTIC
13
COMPARE FADING CHARACTERISTIC WITH THRESHOLDS
14
DOES MEASURED CHARACTERISTIC CROSS THRESHOLD N ?
15
YES
NO
SET SUBSCRIBER UNIT TO N TH TARGET QUALITY LEVEL
16
DOES MEASURED CHARACTERISTIC CROSS THRESHOLD N-1 ?
60
YES
NO
SET SUBSCRIBER UNIT TO N-1 TH TARGET QUALITY LEVEL
61
DOES MEASURED CHARACTERISTIC CROSS THRESHOLD 1 ?
62
NO
YES
SET SUBSCRIBER UNIT TO 1ST TARGET QUALITY LEVEL
63
SEND INFORMATION SIGNAL
19
CALL TERMINADTED ?
17
NO
YES
END
18

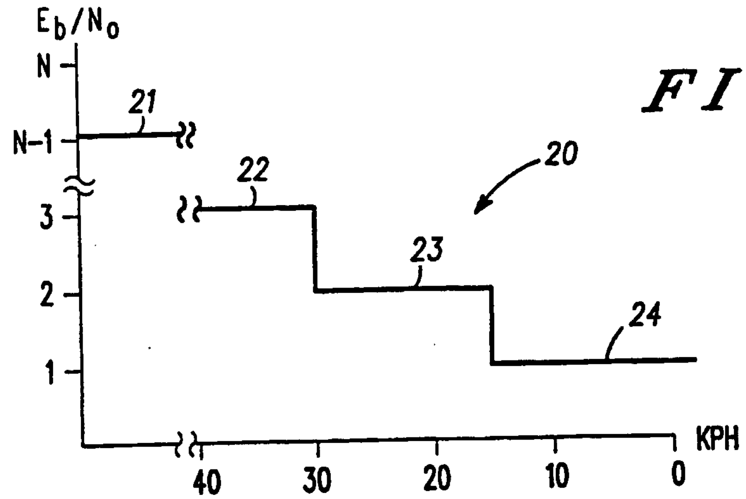


FIG.2

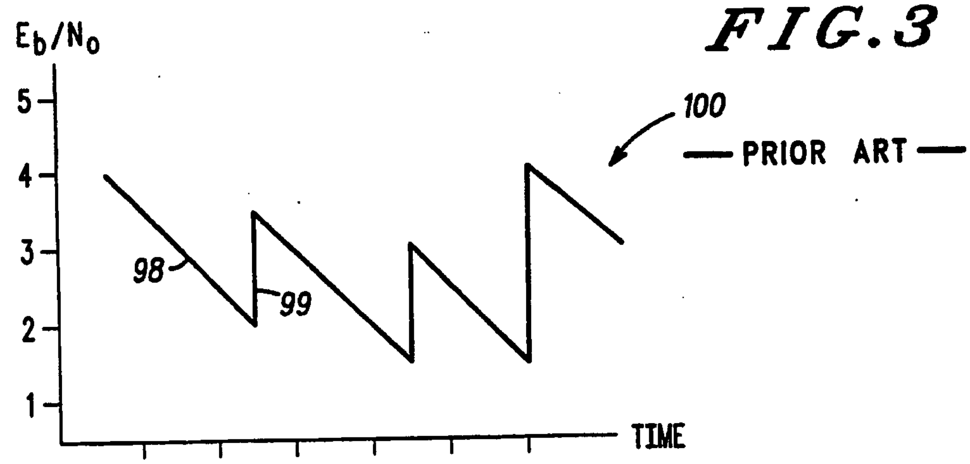


FIG.3

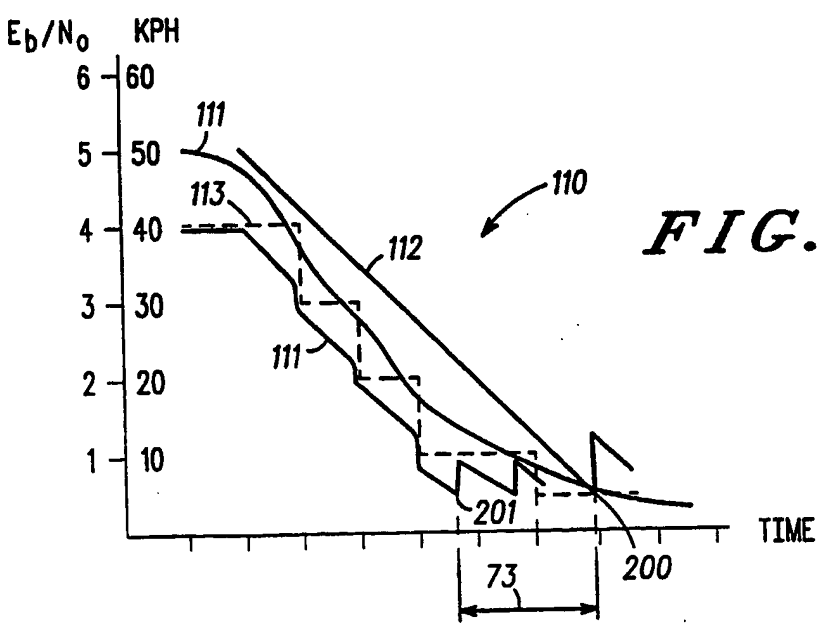


FIG.4

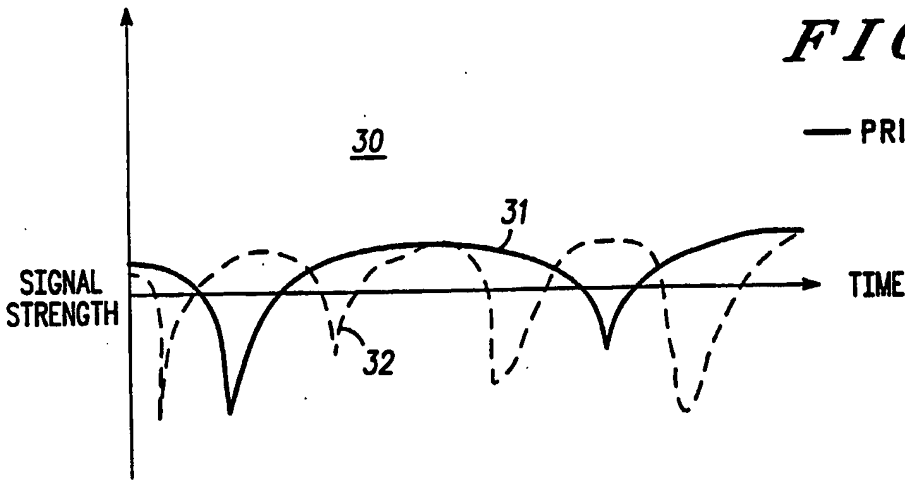


FIG.5
— PRIOR ART —

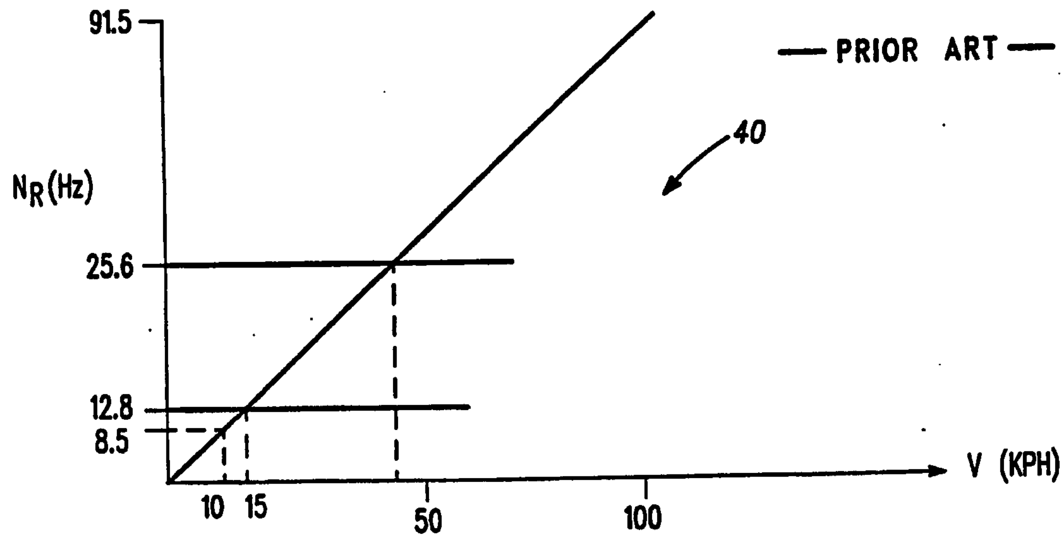


FIG.6
— PRIOR ART —

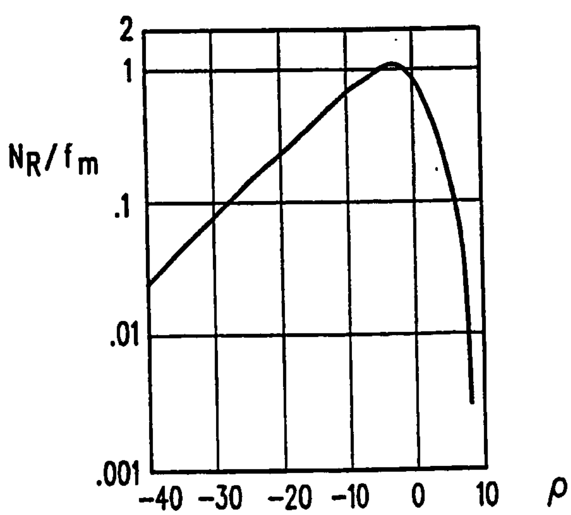
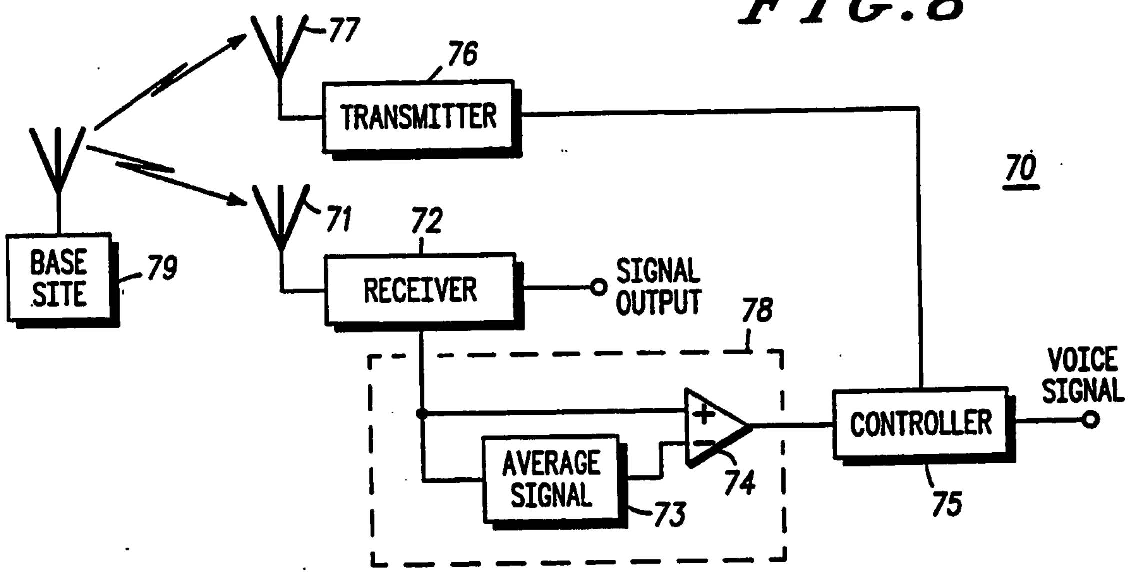


FIG.7
— PRIOR ART —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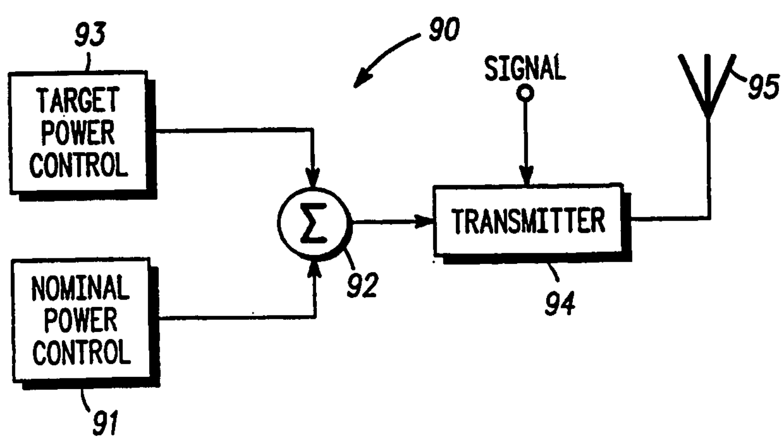
76
TRANSMITTER
70
71
72
BASE SITE
79
RECEIVER
SIGNAL OUTPUT
78
VOICE SIGNAL
+
−
CONTROLLER
AVERAGE SIGNAL
74
73
75

FIG.8

FIG.9


93
90
SIGNAL
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TARGET POWER CONTROL
Σ
TRANSMITTER
NOMINAL POWER CONTROL
92
94
91

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/00835

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :H04B 1/00
US CL : 455/69
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 455/52.1,52.3,65,54.1,54.2,67.1,69,70,89,88,67.6,67.4;375/76

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A, 4,777,653 (BONNEROT ET AL) 11 OCTOBER 1988, COL. 3, LINE 68 TO COL.4, LINE 16, COL. 8	1-5
A	US,A, 4,580,262 (NAYLOR ET AL) 01 APRIL 1986, FIG.1.	1-10
A	US, A, 4,228,538 (SCHARLA-NIELSEN ET AL) 14 OCTOBER 1980, FIG. 2.	1-10
A,P	US, A, 5,239,667 (KANAI) 24 AUGUST 1993, FIG. 1.	1-10
A,P	US, A, 5,245,629 (HALL) 14 SEPTEMBER 1993, FIG.6.	1-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

09 MARCH 1994

Date of mailing of the international search report

25 MAR 1994

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